Sea Ice Surface Thermal States in Polar Regions

S. V. Nghiem

Jet Propulsion Laboratory, California Institute of Technology, MS 300-235
4800 Oak Grove Drive, Pasadena, CA 91109

1 Objectives

This paper discusses the role of submarine as a research platform in conjunction with surface measurements and spaceborne sensing to study sea ice surface thermal states. It is necessary to determine sea ice thermal states to evaluate the overall effects of climatic feedback processes in polar regions under various snow and cloud cover conditions. Such processes need to be investigated at local, aggregate, regional, and global scales with frequent observations.

2 Scientific Issues

Changes in sea ice surface thermal states modify surface albedo, which induces further changes in surface heat balance and subsequent changes in ice surface temperature. These changes are results of complex interactions due to feedback mechanisms under different snow and cloud cover conditions over sea ice of different types and thicknesses. An amplification effect in the ice-albedo feedback process has been long recognized [Croll, 1875] and various simulations of global warming have indicated the importance of the ice-albedo feedback [Ingram et al., 1989].

In the feedback process, cloud cover interferes with the distribution of shortwave and longwave radiations, and thus strongly affects the surface energy balance. Yet is currently uncertain whether the net cloud feedback is positive or negative because of the complexity of ice-albedo cloud feedback mechanisms in the atmosphere-ice-ocean system [Moritz et al., 1993].

Depending on geographical locations and seasonal conditions, effects of clouds on the total surface heat budget can be very different due to the warming `blanket effect' or the cooling `umbrella effect'. However, the resultant temperature changes should represent the overall effects on sea ice thermal states. Temperature is considered as a leading climatic factor and temperature changes characterize climatic changes.

In the above respects, it is necessary to observe sea ice surface thermal states at various scales, over large areas, and with a frequent coverage. The intensive field experiment of the SHEBA program (Surface Heat Budget of the Arctic Ocean) and the extensive field experiments of the Canadian C-ICE program (Collaborative-Interdisciplinary Cryospheric Experiments) address the scientific issues at the local scale over the experimental sites. For the aggregation scale (10-100 km) to the regional and global scales, extensive coverages of coordinated submarine, surface ship, and spaceborne remote sensing measurements are required.

3 Navy Submarine Role

Ice thickness regulates sea ice surface temperature and the temperature change under thermal forcing. Using a heat transport model combined with climatology and radiation data in the central Arctic, Maykut [1978] shows large variations in sea ice surface temperatures over various thickness categories of ice from 0.05 m (thin new ice) to 3 m (very thick ice) during a sea ice season from September to May. The magnitude of ice surface temperature change and net surface heat budget balance for a given atmospheric thermal forcing strongly depend on ice thickness categories [Maykut, 1978]. Furthermore, ice thickness is a good indicator of ice age and snow cover depth.

Submarine sonar data is the richest source of in-situ ice thickness measurements that have been collected over several years for unclassified scientific studies under the SCICEX program [Gossett, 1996]. The area of submarine sampling defined by the Chief of Naval Operations covers a large part of the Arctic region. Submarine sonar data have been taken extensively along submarine cruise tracks over thousands of kilometer under Arctic sea ice. See http://www.ldeo.columbia.edu/SCICEX/ for composite SCICEX tracks from 1993 to 1997. Another submarine cruise is planned for 1999. Such massive submarine data are crucial and most effectively used to determine ice thickness.

Ice thickness from submarine measurements is therefore essential in the development, evaluation, and validation of observation techniques and algorithms using remote sensing data to address the scientific issues. Thus, an important requirement for submarine measurements is the coordination with concurrent satellite sensors. This is particularly relevant to infrared-visible passive sensors used to detect clouds because of cloud dynamics. Microwave radars can see through clouds to detect sea ice surface thermal conditions. The magnitude of radar backscatter change is dependent on ice thickness categories. Because of ice motion, the data coordination is necessary.

Submarine data acquired in the past can be used with remote sensors operated during that time frame. However, future remote sensors, both active and passive, are more advanced with polarization diversity, higher resolutions, larger coverages, and more frequent observations. Furthermore, we have proposed the concept of formation flights of spacecrafts carrying different active and passive sensors to utilize the strengths of both with data from different sensors collocated in time and space to deal with the dynamics of sea ice, clouds, and climate systems. New algorithms need to be developed and coordinated concurrent submarine data are required for the future missions.

4 References

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Acknowledgments

The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.